N.A.S.A. NGL-05-003-024

EPL 74-2

ENVIRONMENTAL PHYSIOLOGY LABORATORY

RESULTS FROM THE EPL MONKEY-POD EXPERIMENT CONDUCTED AS PART OF THE 1974 NASA/MSFC CVT/GPL III

(NASA-CR-148736) RESULTS FROM THE EPL MONKEY-POD EXPERIMENT CONDUCTED AS PART OF THE 1974 NASA-AMES CVT/GPL 3 (California Univ.) 55 p HC $4.50 CSCL 06D

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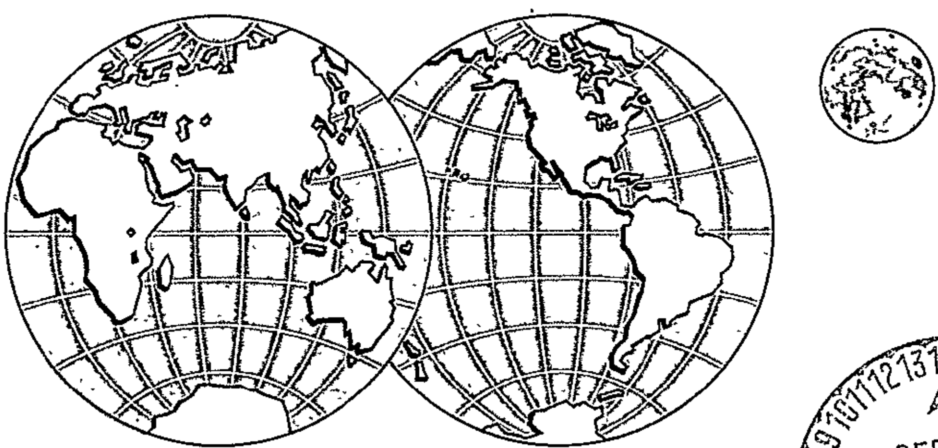

UNIVERSITY OF CALIFORNIA - BERKELEY

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RESULTS FROM THE EPL MONKEY-POD EXPERIMENT CONDUCTED AS PART OF THE 1974 NASA/MSFC CVT/GPL III

Work performed under NASA Grant NGL 05-003-024

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15 October 1974

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1.0. Introduction and Purpose of Report.

This report documents the participation of the Environmental Physiology Laboratory (EPL) of the University of California, Berkeley in the NASA/Marshall Space Flight Center (MSFC) General Purpose Laboratory Concept Verification Test III (CVT/GPL III). Under NASA Grant NGL 05-003-024 to the University of California, Berkeley, Professor Nello Pace, Principal Investigator and Dr. Bernard D. Newsom, NASA/Ames Research Center (ARC) Scientific Monitor, a fiberglass pod system has been developed to house a 10-12 kg macaque monkey continuously in comfortable restraint for periods of 10 days or more under the weightless conditions of space flight.

Four major elements comprise the EPL Monkey Pod Experiment System:

i) a fiberglass pod containing the instrumented monkey plus feeder and watering devices;

ii) an inner console containing the SKYLAB mass spectrometer with its associated valving and electronic controls, sensing, control and monitoring units for lower body negative pressure (LBNP), feeder activity, waterer activity, temperatures, and gas metabolism calibration;

iii) an umbilical complex comprising gas flow lines and electrical cabling between the inner and outer console;

iv) an outer console in principle representing the experiment support to be provided from general spacecraft sources.

Strip chart recorders near the outer console were to be furnished by NASA/MSFC.

A previous report from this laboratory, EPL 74-1 "Results from the EPL Monkey-Pod Experiment Conducted as Part of the 1974 NASA/Ames Shuttle CVT-II" contains an expanded description of the design and operation of the total

experiment package.

The design of EPL Monkey Pod Experiment for CVT/GPL Test III was such that EPL personnel would continuously monitor the physiological status of the animal and the progress of the experiment at the outer console station, while a NASA/ARC Payload Specialist would carry out the daily activity schedule.

2.0. Applicable Documents.

Semi-Annual Status Reports #18-#24
1 August 1970 to 31 January 1974
NGL 05-003-024

The Automated Primate Research Laboratory (APRL)
Final Report for Contract NSR 05-003-233 between NASA and the Regents of the University of California, EPL 72-1, 1 July 1972.

A Monkey Metabolism Pod for Space-Flight Weightlessness Studies.
N. Pace, D. F. Rahlmann, A. M. Kodama, R. C. Mains and B. W. Grunbaum
L.5.7 COSPAR 1973

EPL Documentation File for NASA/Ames CVT II Trials, 1974

EPL - NASA/Ames CVT II Log, 1974

EPL 74-1 Results from the EPL Monkey Pod Experiment Conducted as Part of the 1974 NASA/Ames Shuttle CVT II. Report prepared by D. F. Rahlmann, A. M. Kodama, R. C. Mains and N. Pace. 10 June 1974.

EPL Documentation File for NASA/CVT/GPL Test III at MSFC, 1974

EPL - NASA CVT/GPL III Log, 1974

CVT/GPL Phase III Test Plan NASA/MSFC 10M33227. 1 July 1974.

Strip chart records for Monkey Pod Experiment from Simulated Ground Link Data Acquisition Center 14-19 July 1974 at MSFC.

3.0. Background.

In accordance with milestone chart "ARC Bioresearch Lab Breadboard Test II for CVT - Milestones", preparation of the EPL monkey pod experiment for the CVT/GPL III at MSFC was initiated immediately upon the conclusion of test

activity at NASA/ARC on 26 April 1974. The major equipment and experimental monkeys were returned to Berkeley on 29 April 1974, followed by the calibration gas cylinders and vacuum pump oil on 30 April 1974.

During May through July updated informational exchange from EPL was conveyed by telephone and mail to ARC and MSFC.

Dr. D. F. Rahlmann of EPL was again assigned responsibility as EPL Monkey Pod Experiment Coordinator. Dr. A. M. Kodama and Mr. R. C. Mains from EPL were at MSFC prior to and during the initial phases of the test run. Mr. F. Vilao and Mr. C. E. Haglund assisted with various aspects of the electronic and mechanical preparation of the EPL experiment prior to shipment to MSFC.

3.1. Meetings.

On 5 July 1974 a preshipment meeting was conducted by Dr. S. T. Taketa of NASA/ARC. Dr. D. F. Rahlmann attended this meeting in Room 209, Bldg. 236 as a representative of EPL.

During the course of the test run at MSFC all announced meetings were attended by one to three representatives of EPL.

3.2. Interim Groundwork at EPL.

Several changes were made in the instrumentation modules at EPL during the interim between the conclusion of the NASA/ARC CVT II test and the transfer of pod equipment to ARC for crating on 25 June 1974. Following the modifications to the bioinstrumentation which are indicated later in this paragraph, a 5.2-day monkey-instrumentation-interface test was conducted at EPL from 12 June - 17 June 1974.

i) Mass Spectrometer Sensor System.

A malfunction of this instrument was discovered early in the month of

June. After thorough exploration of corrective procedures at EPL in conjunction with advice from the manufacturer, it was deemed necessary to remove the sealed aluminum cylinder from the inner console and hand carry the instrument to the Perkin-Elmer plant in Pomona, California for repair. The remedial measures were made within 24 hours, and the component was returned to EPL, Berkeley.

With the exception of a higher ion-pump current reading than that indicated originally upon receipt of the instrument from JSC, the system functioned satisfactorily throughout the test. Following removal of the test animal, the mass spectrometer was set in standby mode while current output of the ion pump was observed until 24 June 1974. At this time, main AC power switches were turned off, and the front protective plate was attached for shipment the following day.

ii) Inner Console.

This system was modified to accept all interfaces from the pod and, in turn, interface directly with the outer console. In previous tests some gas lines had run directly from the pod to the outer console.

The LBNP control system was mounted with the inner console. Although this total unit was only 1.6 meters in height, a requirement demanded by restrictions of the airplane cargo bay area for shipment to MSFC dictated its removal during this phase of transport. As a result, the interface of the LBNP control was modified to facilitate removal and replacement.

A three-way temperature sensor was added to the inner console. Thus, lower pod, upper pod, and gas temperatures entering the mass spectrometer could be monitored continuously.

iii) Differential Pressure Between Upper and Lower Pod.

During an EPL trial period an outboard leak was varied on the gas line proximally to the lower pod pump, in order to determine the optimal flow rate.

The rate finally adopted produced no detectable difference in pressure between the upper and lower pod, thus maintaining the accuracy of continuous respiratory gas measurements and preventing excessive accumulation of water within the lower pod.

iv) Outer Consc__.

This unit was modified to approximate more closely available support from general spacecraft sources than on previous trials. Four vacuum pumps for the upper pod, lower pod, LBNP and the mass spectrometer systems are incorporated within this console, in addition to a 28V DC power supply.

Gas cylinders were still maintained in conjunction with the outer console for purposes of calibration.

Data acquisition channels were also interfaced to pen-writing recorders through the outer console.

v) Monkey Pod.

The restraint-jacket skirt was modified to produce an asymmetrical cone shape. This change allowed more freedom of movement and greatly facilitated the positioning of the skirt periphery beneath the compression and retainer rings during insertion.

Elbowed 90° exhaust ports were designed and fabricated for use on the pod. The metal fabrication and welding are equivalent to aircraft specifications. The ports permitted the use of a minimum length of gas lines to the inner console, and could be utilized with pods on either side of the inner console.

During EPL testing the waterer functioned adequately in all aspects. Mechanically, the feeder was activated without difficulty; however, the feeding activity signal could not be detected electronically. In addition,

the food counter produced erroneous results. Upon conclusion of the trial, a capacitor within the feeder control box was replaced and the feeder system performed according to specifications.

A smaller and lighter weight connector and cable (I.M.I. Division of Becton-Dickinson) replaced the previously used Grass unit in the transmission of ECG hardwire data.

vi) Umbilical Lead.

This element of the monkey pod experiment package was extended in length to accommodate a distance of 6.1 meters from inner to outer console. This extension was recommended by MSFC to allow placement within the GPL mockup.

3.3. Movement of EPL Major Equipment and Test Monkeys.

EPL-furnished equipment was prepared for shipment to NASA/Ames, where it was prepared for transport by a NASA Grumman Gulfstream aircraft (NIONA) to the test site at MSFC. A listing of these milestones is as follows:

Date	Items	Disposition
11 Jun 1974	4 H-size calibrated gas cylinders 1 package vacuum pump oil	By NASA/ARC scheduled truck and reshipped by truck to MSFC.
25 Jun 1974	8 pieces of EPL monkey pod experiment equipment 1) Monkey pod, less feeder & waterer 2) Inner console 3) Outer console 4) LBNP control box 5) Vacuum pump 6) Gas regulators 7) Cryopump assembly 8) Large metal box containing interfacing connectors, feeder, waterer, tool boxes, etc.	Contract, North American Van Lines
8 July 1974	2 male pig-tailed monkeys, individually caged in NASA/ARC supplied transport cages. Personal luggage of EPL representative, D. F. Rahlmann.	Transport in covered van and accompanied by ARC veterinarian and EPL representative.

8 July 1974	EPL pod experiment secured on board for air transport.	Placed in NASA Grumman Gulfstream turboprop.
9 July 1974	All experimental animals moved from Bldg. 236 in transport cages to placement on aircraft. Personal gear of 2 passengers secured.	Take off for MSFC at 0530 hrs PDT

Equipment containers including the inner console were secured within the aircraft without regard for labels which indicated a position for a particular end. The interior dimensions of the aircraft and the need to place the bulk of the load forward in the cargo bay to maintain stability while the aircraft was on the ground were overriding considerations.

The total payload aboard the NASA aircraft was in excess of 1,400 kg. Pressurization within the aircraft was maintained below the equivalent of 1.5 km. During most of the flight the aircraft traveled at an altitude 5.8 or 6.4 km above sea level. Temperature within the passenger and cargo bay was maintained between 18° and 25°C and was recorded throughout the flight. At 1015 hrs, 9 July 1974, a refueling stop was made at Tinker Air Force Base, Oklahoma City, Oklahoma. Prior to landing, the cabin temperature was lowered below 21°C, cargo bay doors remained closed during the stop, and on takeoff at 1100 hrs the cabin temperature had not exceeded the specified limits. This was accomplished without auxiliary equipment. Ambient temperature outside the aircraft exceeded 32°C.

Arrival time at the NASA hangar at MSFC was at 1330 hrs PDT (1530 CDT local time). The experimental animals with ancillary care packages were immediately transferred to an air-conditioned transport van and convoyed with a leading security patrol vehicle, wrecker, several sedans and station wagons plus a rear security vehicle. The entourage proceeded east from the NASA hangar to Rideout Road and then south to Bldg. 4612. An animal holding quarter

designated as the BCR (Bioclean Room) had been temporarily located within this building. All experimental animals were transferred to the BCR and maintained within the same room. Although each of the 5 non-human primates of 3 different species were individually caged, they were in proximity to 2 roosters and 16 rats.

The EPL test subjects, 2 adult male pig-tailed monkeys *(Macaca nemestrina)* #337, Simple and #341, Philostrate, were in good condition throughout the flight and no gross behavioral or physical abnormalities were noted upon their release into the BCR colony cages. Temperature and humidity in the BCR were maintained within predesignated limits throughout the test period as indicated by continuous chart recordings.

The crates provided by NASA/ARC for several pieces of EPL major equipment were not identified as to content, although weights were indicated. Identification markings were placed on each crate when opened at MSFC in Bldg. 4619 prior to installation of equipment in the GPL.

In preparation for the return trip, the EPL monkey pod experiment modules were separated, and interfacing instrumentation was stowed in designated containers following conclusion of the test on Friday, 19 July 1974. On Saturday, 20 July 1974, supervision of the final crating in preparation for aircraft transportation was observed by the EPL representative. Placement of the experimental monkeys in transport cages was accomplished on Monday, 22 July 1974. Movement of animals within an air-conditioned van to the NASA hangar was carried out with a smaller convoy of vehicles than was used on arrival.

Take off from MSFC was at 0905 hours (CDT) 22 July 1974. The same NASA aircraft, with a change of two of the three crew members, was in service for the flight west. On this trip the crate containing the inner console was

secured in an upright position. A refueling stop was made at Kirkland Air Force Base, Albuquerque, New Mexico. The control of temperature and humidity in the cargo bay while the aircraft was on the ground was accomplished in a similar manner as described for the eastward flight. Arrival at Moffett Field was at 1500 hrs PDT. Return of the two EPL experimental monkeys to EPL was carried out by Dr. R. Simmonds of NASA/ARC and Dr. D. F. Rahlmann of EPL. The test monkeys were individually caged in isolation quarantine at EPL by 1630 hrs (PDT) 22 July 1974. Food and water were made available. Behavior and physical appearance of both monkeys were within normal limits.

The shipping department of NASA/ARC returned all major equipment to EPL on 25 July 1974.

Dr. D. F. Rahlmann of EPL accompanied the experimental equipment with Dr. R. Simmonds of NASA/ARC aboard the NASA aircraft and was at MSFC throughout the test. Dr. A. M. Kodama and Mr. R. C. Mains arrived at Huntsville Jetport on the evening of 10 June 1974. Mr. Mains returned to EPL on 16 July and Dr. Kodama on the following day by commercial airline.

3.4. Pre-test Installation at MSFC.

On 10 July 1974 an introductory briefing meeting of test participants was held in the upstairs offices located in the west end of the high-bay area of Bldg. 4619. Within this same area, desk space and telephones were also allocated to experimenters. All 8 packages of EPL monkey pod experiment equipment were delivered to the immediate vicinity of the GPL within Bldg. 4619. Following the aforementioned meeting, packing crates were carefully removed and stored. All EPL equipment appeared to be in good condition. The monkey pod and inner console were set in place within the GPL. The feeder and waterer were removed from the metal transport container and installed within

the upper pod. All animal care and insertion equipment was removed from the metal container and moved to the BCR. The outer console was placed on a large pallet platform in proximity to the GPL. Finally, the length of the prepared umbilical was laid out to check its linear dimension from inner to outer console.

On 11-12 July 1974 all elements of the EPL monkey pod experiment, less the monkey, were integrated and connected to the available electrical and vacuum sources. As in NASA/ARC CVT II, a single source of electrical power was used to supply all the EPL experimental equipment and the strip chart recorders. The availability of on-board vacuum sources at MSFC was utilized for the operation of the mass spectrometer and the control of air flow in the upper and lower pod, thus more closely simulating conditions expected in Spacelab.

An audio communications link was provided from within the GPL to the location on the pallet where continuous strip-chart recordings would be made during the test. Recorder compatibility presented some problems, particularly with the Brush Biotach channel. As a backup heart-rate channel, a BT-1200 Biotach (E & M Instrument Co., Houston) was installed in parallel and used during the test run in addition to the Brush Biotach.

The feeder electronics initiated a spurious signal to the totalizer and did not provide an adequate activity signal to the recorder. Line checks were made and the problem appeared to arise from the power supply box mounted within the inner console. As considerable displacement of other properly functioning elements within the inner console would be involved to remove the power supply, and since the water activity could still be monitored, it was decided to forego the continuous measurement of food intake activity during the test.

Examination on return of the feeder to EPL revealed a misaligned photo transistor which sensed the interruption of the light path from the light-emitting diode whenever a food tablet was presented. This failing probably

occurred during shipment from EPL to MSFC. Corrective action at the present time will be to eliminate this electronic portion of the feeder system and rely on a contact switch activated by the food lever to signal the tablets delivered to the test monkey.

Total food consumption and periodic food intake activity could be determined by the number of tablets added to the reservoir at morning and afternoon experiment calibration periods. Mechanically, the feeder functioned normally, so there was adequate assurance that the test monkey would receive the food tablets whenever the lever was actuated. All other aspects of the bioinstrumentation from sensors to recorder performed within specifications.

Mechanical and electronic checks were repeated on Saturday, 13 July 1974, and all experiment bioinstrumentation appeared to be ready for animal insertion scheduled for the following day.

4.0. Test Activity.

A protocol for monkey insertion and a daily test activity schedule developed by EPL and tested during the NASA/ARC CVT II 15-26 April 1974 was proposed by EPL for the NASA/MSFC CVT/GPL III. A step by step procedural list which was carried out by the Payload Specialist, Dr. S. T. Taketa, is shown in Appendix B. Although a L/D 12/12 schedule was planned for illumination within the GPL, conditions experienced in regard to temperature and humidity necessitated the entry of personnel during some hours of darkness. For example, according to the MSFC test log during the night of 15 July 1974 several entries of 5 minutes duration were made between 1945 and 2225 hrs CDT. In addition, the EPL experiment coordinator, following receipt of a phone call from the night test monitor entered the test module for a 2-minute period at 2130 hrs on 18 July 1974. The situation at the time called for a judgment decision of

a responsible individual in regard to the condition of the test animal. A slight amount of fluid urine was noted in the LBNP line which was not deemed detrimental to the physiological well-being of the test subject. Subsequent observations prior to and during monkey removal from the pod on 19 July proved that the animal was in good condition. Further substantiation of this fact is indicated in the test results section of this document.

It was also noted that lights on in the GPL did not occur according to an indicated schedule at 0700 hrs CDT, but were actually on at 0635 hrs and in turn darkness was initiated at 1835 hrs.

4.1. Schedule of EPL Monkey Pod Experiment, 14 July to 19 July 1974.

Daily observations were made by the EPL experiment coordinator of the two potential pod-test monkeys, #337, Simple and #341, Philostrate, from 9 to 14 July 1974 at the BCR in Bldg. 4612 at MSFC. The BCR was monitored 24 hours a day by MSFC test support personnel. On 14 July 1974, #337, Simple was selected as the test subject. Both animals were in good condition as judged on the basis of behavior, gross appearance and nutrient intake. However, #341, Philostrate had exhibited a slight tendency toward the production of soft feces the day after his arrival at MSFC.

Insertion of the candidate monkey into pod was carried out within the BCR. Transportation to the test site by air-conditioned van and interfacing with the balance of the experiment instrumentation in the GPL was accomplished by 1250 hrs CDT on 14 July 1974. Continuous data flow was recorded from this time to 0900 hrs on 19 July 1974. Thus, test duration was 116 hours or 4.83 days. From insertion of the monkey in the pod (1200 hrs, 14 July) to removal (1100 hrs, 19 July), the total elapsed time was 119 hours or 4.96 days.

Nutrient intake checkpoints and calibration periods were initiated each day as follows:

Date Day Mo.	Starting Time (CDT) hrs	Time to Completion (min)	Task Performer
14 July	1600	50	A. M. Kodama D. F. Rahlmann
15 July	0910	70	S. T. Taketa
15 July	1446	85	S. T. Taketa
16 July	0900	58	S. T. Taketa
16 July	1445	70	S. T. Taketa
17 July	0834	63	S. T. Taketa
17 July	1502	58	S. T. Taketa
18 July	0837	70	S. T. Taketa
18 July	1440	50	S. T. Taketa
19 July	0811	50	D. F. Rahlmann

5.0. Test Results.

From 15 July to 18 July, as indicated in paragraph 4.1., the Payload Specialist performed all functions required by the EPL monkey-pod experiment schedule within the GPL. Monitoring of continuous data channels from recorders mounted on the pallet was accomplished by EPL representatives. A two-way audio communication link was also provided on pallet. Thus, informational requests and exchange could be maintained between the exterior and interior of the GPL. One of the TV cameras within the GPL was also used to view the condition of the EPL pod and inner console, but could only be monitored within the test control room 158A of Bldg. 4619. Results reported in following paragraphs were obtained from data monitored continuously on Brush Strip Chart Recorders and from calibration data sheets.

5.1. Monkey Insertion Procedures.

At 1200 hrs CDT on 14 July 1974, monkey #337, Simple was injected intramuscularly with 70 mg of Ketaset$^{(R)}$ plus added atropine sulfate solution. A body weight of 11.00 kg was determined for the subject following tranquilization. During insertion procedures a deep laceration of the right palmar surface was noted. However, this injury was not infected and it was decided to proceed without adjunctive medical treatment. The preparation of the test animal was carried out by Dr. D. F. Rahlmann and Mr. R. C. Mains of EPL, with assistance of Dr. R. Simmonds of NASA/ARC.

All insertion procedures were carried out in the same manner as previously reported. The ECG electrode paste applied was a product developed by NASA for use on Apollo astronauts (1090 Biogel manufactured by Biocom Inc., 9522 W. Jefferson Blvd., Culver City, California).

The transport van used to move the monkey and pod module from the BCR to the GPL was of sufficient dimension to allow proper positioning in an upright mode. At 1250 hrs CDT the pod was interfaced within the GPL and continuous data flow initiated. A volume of 1,000 ml of water was added to the waterer and 150 tablets of 5040 PMC were added to the food reservoir.

5.2. Monkey Condition and Nutrient Intake.

As noted in paragraph 3.4, the food tablet totalizer did not function reliably prior to the test, and this condition persisted throughout the test. During observational periods it was noted the monkey used his left hand to operate the food lever. The right hand laceration mentioned in paragraph 5.1 no doubt contributed to this behavioral pattern. Upon removal of the monkey at the end of the test, the injured hand had healed well, and no evidence of infection was observed. All water offered was consumed within a 24-hr period.

No skin irritation was evident from jacket, other restraint garments or ECG electrodes.

Of interest in relation to the condition of the monkey are the temperatures recorded within the upper pod and the temperatures at the lower pod outlet. The temperature data recorded twice daily are shown in Table 1. Temperatures in the upper pod ranged from 23.3° to 25.1°C, and are well within the ambient temperatures where the pig-tailed monkey may be expected to maintain thermal equilibrium (refer to EPL Semi-Annual Status Reports #21-#24).

5.2.1. Body Weight Changes.

The body weight of #337, Simple remained essentially constant during the test period. A negligible loss of 0.04 kg as determined by measurements at insertion and removal was noted. In contrast to NASA/ARC CVT II the subject consumed an adequate amount of food during the trial. Table 2 contains the body weight data and the total amount of nutrients consumed.

The weight of #337, Simple was taken at several times during the month of July 1974, as indicated in Table 3. Considering that the weights recorded during this period were obtained at different post-prandial times, there is no indication that the air and ground transportation of the subject caused any gross decrement in his physiological status. Variations in body weight for the range indicated in Table 3 have been noted for healthy adult male pig-tailed monkeys maintained in the EPL colony.

5.2.2. Metabolism in Relation to Energy Intake.

Considering the mean weight of #337, Simple at 10.98 kg (the average of insertion and removal weights), a resting metabolic rate was calculated from

relationship $M = 72W^{0.75}$ where M = resting metabolic rate in kcal per 24 hrs and W = the monkey weight in kilograms. In addition, the mean daily caloric intake was calculated from the known weight of each 5040 PMC tablet (0.79 g) and the caloric value of food (3.49 kcal/g). Essentially, the monkey maintained his total body weight during the trial and 267 kcal/day of food energy were available for metabolic utilization above basal resting requirements. The results are summarized in Table 4. As will be indicated in the following section (paragraph 5.2.3.) food intake was reduced during the 20 hours prior to animal removal from the test and no doubt considerably influenced the calculation of 24-hr mean for caloric intake. On the whole, however, it is evident that the monkey maintained energy balance during NASA/MSFC CVT/GPL III.

5.2.3. Food and Water Activity.

As noted in paragraph 3.4., individual activation of the food dispenser was not obtained on the strip chart records. However, during the test, food tablets were always available to the monkey and replenishment of the food reservoir was accomplished with a known amount of tablets added at a precise time. Thus, it may be assumed that the monkey ate the number of food tablets that needed to be added to the reservoir during any time period. Table 5 contains a periodic summary of food tablets added to the reservoir and the amount of water consumed. In all cases the major portion of the food and water was consumed during morning and early afternoon hours. Although the feeder was mechanically functional throughout the test, no food was consumed during the hours prior to removal. In this time frame other experiments were being removed from within the GPL and the surrounding activity levels were not controlled or scheduled as had been the case on days 15-17 July 1974.

Table 6 contains an hourly summary of water intake activity. The rating system from 0, with no activity, to a maximum of 3 has been previously explained in report EPL 74-1 "Results from the EPL Monkey-Pod Experiment Conducted as Part of the 1974 NASA/Ames Shuttle CVT II" (page 10, paragraph 5.2.3.). Continuous strip chart recordings were obtained for water intake and the number of 10-minute periods involved with this activity was 50, or 7.0% of the total test time of 714 10-minute epochs. This figure closely compares to a percentage of 6.2% derived from the previous CVT pod trial with this monkey reported in EPL 74-1, Table 7, p. 28.

5.3. Cardiovascular Data.

Continuous average heart rate data from ECG electrodes were obtained throughout the test. The ECG wave form was still of high quality on 19 July, the recorded signal being as free from artifact as when the electrodes were originally placed 5 days earlier. It was noted on removal of the monkey from the pod that the ECG electrode paste holders contained an adequate quantity of contact medium (Biogel 1090). From 1830 on 14 July to 0730 on 15 July, drift problems were encountered with the electronic conditioning and recording of average heart rate. This situation was corrected, and reliable data as shown by intermittent calibration and ECG tracings were collected for the balance of the trial. The Brush chart speed was set at 0.05 mm/sec for the bulk of the recording time. ECG tracings were recorded at a speed of 5, 10, and 20 mm/sec. During LBNP application the chart speed was changed to 0.20 mm/sec.

5.3.1. Heart Rate and Electrocardiographic Data, 14 July - 19 July 1974.

A summary of hourly average heart rates of #337, Simple is presented in Table 7. During the trial, heart rates as low as 75 and high in excess

of 200 were transiently observed. The mean daily heart rate of 108 beats per minute was only slightly higher than that recorded for the same subject during NASA/ARC CVT II. Biorhythmicity was evident with the highest average 6-hr rate (119 beats/min) occurring in the morning daylight hours, the lowest (95 beats/min) with the hours in darkness from 0000 to 0600 hrs.

Heart-rate changes in relationship to lower body negative pressure (LBNP) will be considered in paragraph 5.5.1. of this report.

5.4. Respiratory Gas Measurements.

Respiratory gas exchange measurements were carried out on the test animal by monitoring the air outflow from the upper pod with a NASA mass spectrometer described in Report EPL 74-1.

5.4.1. Operational Performance - Mass Spectrometer.

As will be seen below, the Skylab mass spectrometer performance during the test was again very satisfactory. Unfortunately, problems in some of the associated hardware, first encountered during NASA/ARC CVT II, continued to be troublesome. The basic difficulty stems from drifts in controls intended to maintain a 5 p.s.i.a. atmosphere for the Skylab series mass spectrometer. Inasmuch as the mass spectrometer measures the partial pressures of gases in a sample, drifts in sample inlet pressure cause corresponding drifts in signal outputs.

Following NASA/ARC CVT II and prior to NASA/MSFC CVT/GPL III, it was hoped that some solution to the problem of fluctuating sample inlet pressure could be obtained. The NASA/JSC designed and assembled a "ratio network" for converting the mass spectrometer signal outputs from gas partial pressures to gas fractions which would have circumvented the problem by making the outputs independent of total inlet pressure. Regrettably, the unit was lost in shipmen

from Houston to Berkeley. A parallel effort to reduce the problem by using an additional pressure regulator in the system proved unsatisfactory. Hence, the mass spectrometer/gas metabolism system used at NASA/MSFC was unchanged from that employed earlier at NASA/ARC. In the absence of a direct solution to the problem, the respiratory gas exchange measurement protocol was modified to include continuous recording of the total inlet pressure, with the expectation that a method could be derived to adjust the strip chart records of the gas partial pressures for variations in sample inlet pressure. In order to accomplish the change, however, the P_{N_2} recording channel had to be sacrificed in order to provide a suitable recorder pre-amplifier for the inlet pressure recording channel. The change focuses on another problem area in the operation of the mass spectrometer, namely, that of a continuing deficiency in strip chart recording capability. Many of the respiratory gas exchange parameters need to be recorded in an expanded scale mode in order to obtain the requisite fidelity, and recorder preamplifiers with up to 10 volts of zero suppression capability are required in some cases. Sufficient numbers of recording channels with suitable offset voltage ranges were not available during the trials at ARC and MSFC, and as a result, certain parameters had to be recorded with poor fidelity or not at all.

5.4.2. Data Output.

The above difficulties notwithstanding, satisfactory data were obtained during NASA/MSFC CVT/GPL III. As was the case at ARC, the mass spectrometer inlet pressure drifted considerably during the test, and resulted in gross artifacts in the strip chart records. However, by using calibration curves relating changes in inlet pressure to drifts in signal outputs for P_{O_2} and P_{CO_2} in standard gas mixtures, it was possible to normalize the strip chart data,

and compute respiratory gas exchange on an hour-by-hour basis for the animal during the test. Approximately 4.5 days of continuous gas metabolism data were obtained. The results of O_2 consumption, CO_2 production, and respiratory quotient determinations on Monkey #337 are shown in Tables 8, 9, and 10. During the course of the test, O_2 consumption ranged from 3.10 to 6.08 liters/hour with a mean value of 4.39 liters/hour and a standard deviation of 0.72 liters/hour. CO_2 production ranged from 2.84 to 4.98 liters/hour with a mean value of 3.77 liters/hour and a standard deviation of 0.52 liters/hour. The R.Q. ranged from 0.79 to 0.94 with a mean value of 0.86 and a standard deviation of 0.04.

Table 11 shows consecutive 12-hr means of O_2 consumption, CO_2 production, and R.Q. indicating an alternating pattern in respiratory gas exchange for the light and dark cycles. O_2 consumption and CO_2 production were higher during the day and lower at night. The overall mean O_2 consumption rate during daytime (light) hours was 4.39 liters/hour and that during night-time (dark) hours 4.01 liters/hour. The difference in the means is statistically significant at the $P < 0.01$ level. The mean CO_2 production rate during light hours was 4.12 liters/hour and that during dark hours, 3.51 liters/hour. The difference in means is significant at the $P < 0.01$ level. The mean R.Q. during day-time hours was 0.88 and that during night-time hours, 0.84. The difference in the R.Q. means was also found to be significant at the $P < 0.01$ level.

5.4.3. Reliability and Calibration.

During the scheduled twice-a-day calibration periods, direct readings of the mass spectrometer signal outputs were obtained on a digital voltmeter for samples of cabin air and pod air following adjustment of the inlet pressure to its nominal value. As verification of the reliability of the mass spectrometer measurements of the respiratory gases, the sum of partial pressures of the gases

was compared with the total barometric pressure read from an electronic barometer. As can be seen in Table 12, there was good agreement between the sum of partial pressures for samples of cabin and pod air and the total barometric pressure. The stability of the mass spectrometer can be seen in Table 13, which shows the results of daily measurements of the partial pressures of O_2, CO_2, and N_2 in three calibration gas mixtures.

5.5. Lower Body Negative Pressure.

The procedure followed by the Payload Specialist for conducting each lower body negative pressure (LBNP) test is shown in Appendix B, "Procedures for Payload Specialist during Nutrient Intake Assessment, Respiratory Gas Exchange Calibration and LBNP Test Periods of Monkey Pod CVT/GPL III at NASA/MSFC". The LBNP system calibration procedures are described in Appendix C, "LBNP Calibration Procedures for Monkey Pod CVT/GPL III at NASA/MSFC". The LBNP calibrations were conducted by an EPL representative immediately before and after the CVT/GPL trial.

The LBNP test procedure developed at EPL had to be modified for the CVT due to space limitations in the Spacelab mockup at both ARC and MSFC. It was not possible to tilt the Monkey Pod to the horizontal position during LBNP (see detailed discussion in section 5.5 of document #EPL-74-1). Because of this, instead of 40 torr negative pressure, only 20 torr LBNP was applied to the monkey for a duration of 15 minutes.

Some modifications of the LBNP system were made in the period between the ARC and MSFC CVT. The LBNP control and calibrate operations were moved from the outer to the inner instrument console. Also an upper/lower pod differential pressure gauge was installed as part of the LBNP control system, thus allowing the Payload Specialist to conduct the LBNP test from inside the Spacelab mockup.

A digital or meter display of heart rate mounted on the LBNP control console and in parallel with the data collection system is needed to complete the LBNP control system.

5.5.1. Operational Performance.

The LBNP system performed satisfactorily throughout the trial. The monkey tolerated the procedures well and had no abrasions from the divider assembly upon removal from the Pod. The ECG record was of a high quality during the majority of the LBNP test periods.

5.5.2. Data Output.

The Payload Specialist, Dr. S. T. Taketa, conducted LBNP tests each day on monkey #337 between 1430 and 1600 hours for the first four days of NASA/MSFC CVT/GPL III. The summary heart rate data, including a fifth LBNP test conducted on the GPL experiment installation day, are shown in Table 14. The average increase in heart rate of 15 beats/min is similar to the average increase of 20 beats/min seen with the same monkey and the 14 beats/min seen with monkey #341 during NASA/ARC CVT II.

5.5.3. Reliability and Calibratior

The differential air pressure gauge and the differential strain gauge pressure transducer used to sense the upper/lower pod differential pressure were calibrated with a mercury manometer before and after the trial and were found to be accurate to within $\pm$ 1 torr. A negative pressure control system utilizing a pressure regulator and a vacuum reservoir, similar to the system used during Skylab missions, may be preferable to the variable speed motor/ centrifugal blower system in present use. With automatic pressure regulation the Payload Specialist would have to adjust the pressure only once during LBNP

instead of periodically, as at present. This would allow more time for performing other tasks during this period and potentially provide better negative pressure control.

5.6. Removal of Monkey from Pod.

At 0800 CDT 19 July 1974, separation of the pod with #337, Simple from the inner console was initiated. The plastic portion of the food reservoir was removed and contained 117 tablets. Following transport to the BCR in Bldg. 4612, removal of the animal from the pod began. Tranquilization with Ketaset(R) intramuscularly followed removal of the upper pod hood. Twenty-eight tablets remained within the metal section of the feeder and 2 additional were counted in the upper pod. Removal of all closely associated bioinstrumentation was done as previously described in report EPL 74-1. No edema or skin irritation was evident on examination of the monkey subject. His injured right hand reported in paragraph 5.1 had progressively healed from the condition observed on 14 July. Cage behavior and nutrient consumption following recovery from tranquilization on this date and until his placement in a transport cage of 22 July was within normal limits.

5.7. Excreta Collection.

All excreta produced by the monkey during the test were recovered quantitatively and returned to EPL for biochemical analysis.

5.7.1. Excreta Recovery from Pod.

The urine removed from the lower pod during the trial and stored under refrigeration was added to the excreta collected in the lower pod at the end of the test after removal of the monkey. Distilled water and a rubber spatula were used to wash excreta from the lower portion of the couch into the lower

pod before and after monkey removal. The absorbent paper and formed feces in the lower pod were placed in a 6-gallon plastic container (Saturn(R) Roper Plastic Inc., Los Angeles, California). The remaining fluid was poured into this container through lower front pod port. Two additional cleansings were made of the interior walls of the lower pod, and the wash material again poured into the plastic container. The lid was securely sealed and the container with contents stored under refrigeration until the morning of 22 July 1974.

5.7.2. Shipment and Return to EPL.

An insulated cardboard box, sized to accept the excreta container and surrounding ice packs within "Ziplock" plastic bags, was used for shipment from MSFC to EPL with the test monkeys. The total package was delivered to the biochemistry laboratory of EPL in good condition. No leakage or offensive odors were noted during transport.

5.8. Overview of Physiological Data Return.

Summary graphs for some of the major physiological parameters evaluated in monkey #337, Simple, during the course of CVT/GPL III are shown in Fig. 1. Also shown are the ambient air temperatures within the upper and lower pods, and the light-dark cycles during the test.

It may be seen that the monkey consumed an average of 267 g of food pellets per day, except for the last day of the test when considerable human activity occurred within the GPL attendant upon shutting down the total test. He also consumed 1 liter of water per day. This level of nutrient intake was adequate to maintain body weight in the animal during the 5 days of the test, as shown in Table 2.

Both the heart rate and the respiratory gas exchange displayed marked diurnal changes, as expected theoretically. The heart rate averaged 118

beats/min during the 12 hours of light, and 101 beats/min during the 12 hours of darkness. The oxygen consumption rate averaged 4.87 liters/hr during the light period, and 4.01 liters/hr in the dark. The CO_2 production rate averaged 4.11 liters/hr in the light, and 3.51 liters/hr in the dark. The respiratory quotient remained relatively stable during the entire 5-day test period.

The overall indication from Fig. 1 is of a monkey in good physiological steady state throughout the test. Thus, these measured physiological parameters verify the clinical impression of excellent condition of the monkey before and after CVT/GPL III.

6.0. Summary and Conclusions.

The summary (paragraph 6, p. 20) documented in EPL 74-1 "Results from the EPL Monkey-Pod Experiment Conducted as Part of the 1974 NASA/Ames Shuttle CVT II" is entirely applicable to EPL activities during NASA/MSFC CVT/GPL III. All interfacing aspects of the EPL Monkey-Pod Experiment System, Payload Specialist, non-human primate test subject, and associated bioinstrumentation functioned in a manner that continues to strengthen the feasibility of a flight-worthy package. Concept design, development and testing over several years at EPL have been ultimately rewarding in that a well-controlled physiology experiment can potentially be conducted with the same components in the weight-lessness state and at 1 *g* or above.

The results of this test have also demonstrated the logistical capability of moving the experiment system a substantial distance by air transport. All calibration equipment, with the exception of the gas cylinders for the conduct of the experiment were contained within the space vehicle simulator (GPL). On-board vacuum was utilized and the electrical power input required was well within spacecraft capability.

While the description of the EPL Monkey Pod Experiment was not totally accurate as published on page 7 in Appendix A of the CVT/GPL Phase III Test Plan and Procedures, the stated objectives: 1) to provide additional base-line data prior to space flight, and 2) to provide an operational assessment of the experiment design in a 1 *g* environment, were met.

The monkey subjects were comfortably restrained during the Shuttle payload mockup tests at NASA installations at ARC and MSFC. The test animals were able to be observed visually for general condition while within the pod. No physical injuries were sustained by the animal as a result of restraint garments, yet adequate alimentary and excreta collection requirements were maintained. At the same time, no traumatization of human experimenters directly involved with pre-flight, flight or post-flight activities occurred. In addition, continuous monitoring of heart rate provided added evidence for real time well-being of the monkey throughout the test. Although it was not carried out with these specific tests, the determination of a wide variety of body composition values and blood biochemistries could be accomplished before and after monkey insertion and removal from the pod. Further, as noted in EPL 74-1, access to the monkey is feasible by removal of the pod hood during flight so that blood samples could be obtained in the weightless state. As sacrifice of the animal is not involved in the test protocol, the test subject could be recycled for additional exposures to the Spacelab environment.

With the exception of the metabolic calibrating gases, all equipment needed for the interaction of the Payload Specialist to carry out experiment milestones was on board the simulated space craft. With existing valving and flow lines, however, the needed calibration gas cylinders can be carried on board. As a matter of fact, 2 gas cylinders containing calibration gases are mounted with the NASA mass spectrometer within the inner console. For the

purposes of the test and the need at this time to maintain a precise performance check of the mass spectrometer, additional gases were utilized. The Payload Specialist was able to carry out his duties within the time framework allotted for experiment integrity.

The components of the inner console were mounted to conform to standard specifications of 19 inch electronic racks. These specifications are indicated as modular for the proposed Shuttle Spacelab.

The divider subsystem between the upper and lower pod functioned satisfactorily and essentially no difference in pressure was noted between the sections during the continuous measurement of respiratory gases. The divider system also furnishes an adequate seal for the application of LBNP. All of the associated bioinstrumentation in regard to LBNP was controlled from within the GPL. The procedural protocol for LBNP requested by EPL was successfully accomplished by the Payload Specialist.

The next logical step toward achieving the goals of a Shuttle Payload biological experiment would consist of up-grading the essential EPL monkey-pod bioinstrumentation to flight worthiness. These areas of consideration involving bio-engineering improvement and refinements, can be partially listed as follows:

i) Development, fabrication and testing of a feeding and watering device which will reliably operate in the weightless situation. Toward this accomplishment spring loading may be the answer. In the case of the feeder, spring loaded rigid clear plastic tubes containing a known amount of food tablets could be attached to the metal portion of the feeder for replenishment of the food reservoir.

Water could be added to the watering device by a ball valved syringe. The water reservoir could be spring loaded or consist of a collapsible bag.

ii) Commutating procedures needed for the addition of a second pod for the total EPL experiment configuration, which can feasibly be contained within the centrally located inner console. The inner console as presently constituted is capable of transducing commutated signals for the respiratory gases and heart rate without an increase in overall size of this module. As visualized, the appropriate valving and electronics for this situation can be accommodated for input from 2 monkey pods. The pod itself has been designed with angled removable ports that can interface with minimum distance to connectors on either side of the inner console.

iii) The conversion of the NASA Skylab mass spectrometer presently in the inner console to a version that can be more reliably utilized at an ambient pressure of 1 atmosphere specified for the Shuttle Spacelab. This instrument was originally designed for use at the reduced pressures (1/3 atmosphere) of the Skylab configuration. A vacuum pump and system of inlet and outlet pressure valves are part of the additions that were needed for operational use during these CVT tests. The manufacturer of the instrument (Perkin Elmer) has indicated that modifications for operation at 1 atmosphere can be made readily, and the changes in total inlet pressure experienced with a vacuum pump and valve system would be eliminated.

iv) Testing of a continuous in-flight and ground-link recording system for the real-time interpretation of the physiological status of the test subjects. The pod experiment should be compatible with the specified power input and output handling of data signals for the Spacelab. In addition, the data should be capable of reduction and used to regulate similar conditions for a near simultaneous ground control experiment.

v) Testing of simulated launch and re-entry profiles and procedures with as nearly flight-qualified total experimental package as possible.

The EPL experiment consisting of the inner console and two pods mounted on platform within a ring or sphere could be positioned for simulation of ground and take off modes for the Shuttle. This device could also be used for the simulated weightless condition of recumbency, reproduce the movement of the Spacelab itself prior to lift off and on re-entry, and as a module for any vibration or *g* loading tests deemed necessary for pre-flight reliability and quality assurance.

vi) On-going testing and retesting of potential monkey flight candidates in all aspects of the experiment protocol to develop a pool of subjects which will increase the reliability of the interpretation of data derived from a weightlessness experiment.

7.0. Figure, Tables and Appendices.

Figure

1. Major physiological and environmental parameters measured on pig-tailed monkey #337 during the NASA/MSFC CVT/GPL III EPL Monkey-Pod Experiment.

Tables

Monkey pod temperatures during NASA/MSFC CVT/GPL III.

2. Body weight change and nutrient consumption of the monkey pod experiment subject #337, Simple during NASA/MSFC CVT/GPL III.

3. Body weight milestones for the adult pig-tailed monkey #337, Simple during July 1974.

4. Metabolism in relation to energy intake and body weight for #337, Simple.

5. Period summary of nutrient intake for #337, Simple.

6. Hourly water consumption activity ratings for #337, Simple during NASA/MSFC CVT/GPL III.

7. Heart rate summary of the adult male pig-tailed monkey #337, Simple during NASA/MSFC CVT/GPL III. 14 July - 19 July 1974.

8. Oxygen consumption (liters/hour, STPD) of monkey #337, Simple during NASA/MSFC CVT/GPL III.

9. Carbon dioxide production (liters/hour STPD) of monkey #337, Simple during NASA/MSFC CVT/GPL III.

10. Respiratory quotient of monkey #337, Simple during NASA/MSFC CVT/GPL III.

11. Consecutive 12-hour means of oxygen consumption, carbon dioxide production, and respiratory quotient for monkey #337, Simple during NASA/MSFC CVT/GPL III.

12. Sum of partial pressures measured by NASA mass spectrometer compared with total barometric pressure measured by an electronic barometer.

13. Stability of NASA mass spectrometer as indicated by gas partial pressure measurements of calibration gas mixtures.

14. Effect of 15 minutes of 20 torr LBNP on heart rate when applied to monkey #337, Simple in the upright position during NASA/MSFC CVT/GPL III.

Appendices

A. Acronym List.

B. Procedures for payload specialist during nutrient intake assessment, respiratory gas exchange calibration and LBNP test periods of monkey pod during NASA/MSFC CVT/GPL III.

C. LBNP calibration procedures for monkey pod during NASA/MSFC CVT/GPL III

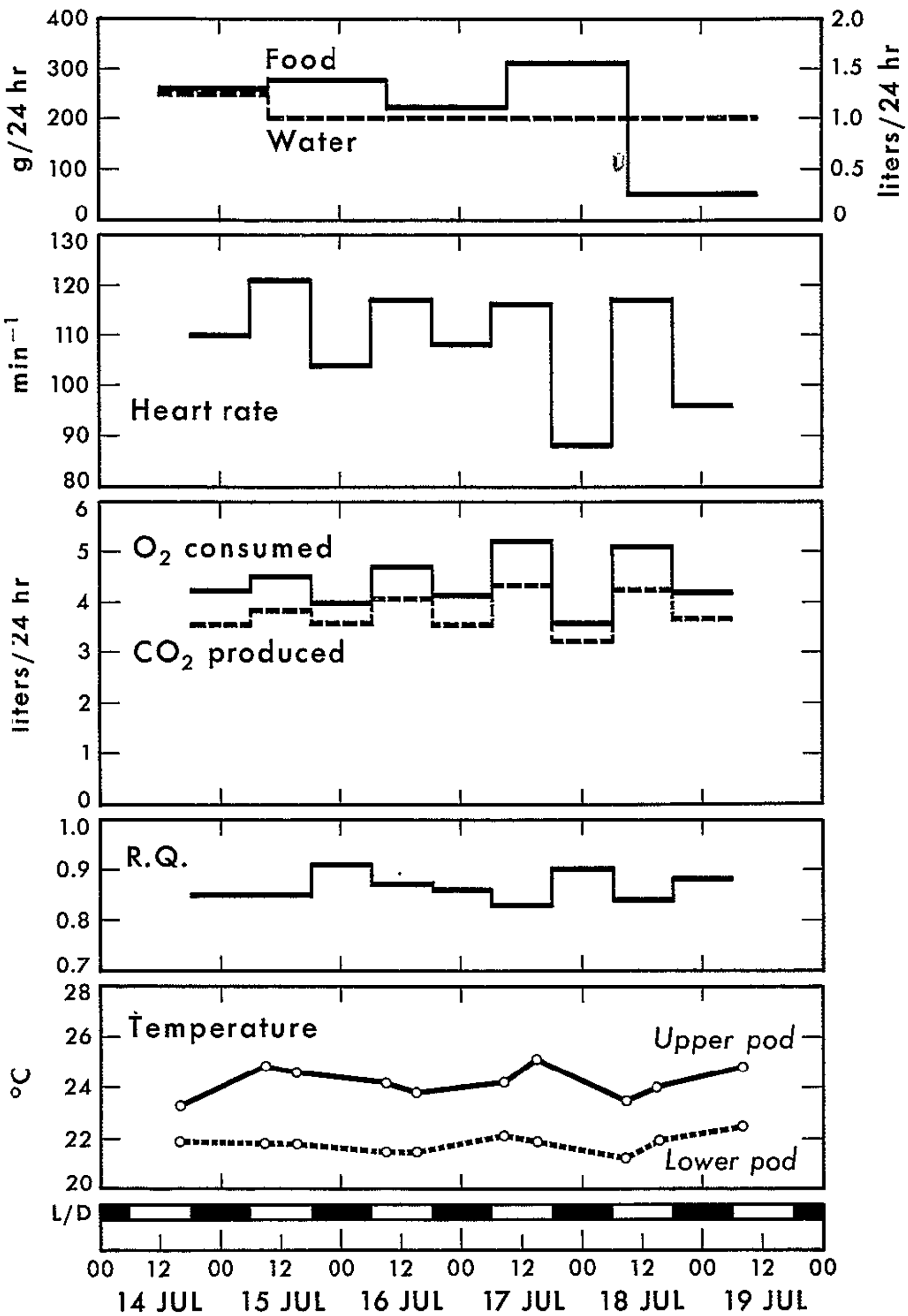

Fig. 1. Major physiological and environmental parameters measured on pig-tailed monkey #337 during the NASA/MSFC CVT/GPL III EPL Monkey-Pod Experiment.

Table 1. Monkey pod temperatures during NASA/MSFC CVT/GPL III.

Date Day Mo.	Time (CDT) Hrs	Temperatures °C Upper Pod	Lower Pod
14 July	1600	23.3	21.9
15 July	0910	24.8	21.8
15 July	1446	24.6	21.8
16 July	0900	24.2	21.5
16 July	1445	23.8	21.5
17 July	0834	24.2	22.1
17 July	1502	25.1	21.9
18 July	0837	23.5	21.2
18 July	1440	24.0	21.9
19 July	0811	24.6	22.5

Table 2. Body weight change and nutrient consumption of the monkey pod experiment subject #337, Simple during NASA/MSFC CVT/GPL III.

Test Duration	Body Weight at Insertion (kg)	Body Weight at Removal (kg)	Nutrients Consumed Food (No. PMC 5040 Tabs)	Nutrients Consumed Water (ml)
14 July - 19 July 119 hrs or 4.96 days	11.00	10.96	1,267	5,250

Table 3. Body weight milestones for the adult pig-tailed monkey #337, Simple during July 1974.

Date (day)	Location Where Weight Determined	Body Wt. (kg)	Milestone
8	EPL	11.28	Prior to shipment to test site.
14	MSFC	11.00	Start of CVT/GPL III.
19	MSFC	10.96	End of CVT/GPL III.
30	EPL	11.41	Clinical check during EPL quarantine period.

Table 4. Metabolism in relation to energy intake and body weight for #337, Simple.

Mean Body Weight During Test (kg)	Metabolic Body Size $Wt^{0.75}$ (kg)	Computed Resting Metabolic Rate $M=72wt^{0.75}$ (kcal/24hr)	Food Intake* (kcal/24hr)	Intake Minus Computed Resting Metabolic Rate (kcal/24hr)	Body Weight Change (kg/24 hr)
10.98	6.03	434	701	+267	-0.008

* Assuming the weight of one 5040 PMC food tablet = 0.79 g, with a caloric value = 3.49 kcal/g.

Table 5. Period summary of nutrient intake for #337, Simple.

	Time Period				Duration of Period (hrs)	Number of Food Tablets Added to Feeder		Water Consumed During Period	
	Start		End						
	Hour	Date	Hour	Date		Total	Mean Intake/Hr	Total	Mean Intake/Hr
I	1200	14 Jul	1600	14 Jul	4.0	256	64	920	230
II	1600	14 Jul	0930	15 Jul	17.5	75	4	330	19
III	0930	15 Jul	1500	15 Jul	5.5	200	36	880	160
IV	1500	15 Jul	0900	16 Jul	18.0	150	8	120	7
V	0900	16 Jul	1500	16 Jul	6.0	184	31	1,000	167
VI	1500	16 Jul	0900	17 Jul	18.0	95	5	0	0
VII	0900	17 Jul	1500	17 Jul	6.0	224	37	1,000	167
VIII	1500	17 Jul	0900	18 Jul	18.0	168	9	0	0
IX	0900	18 Jul	1500	18 Jul	6.0	62	10	1,000	167
X	1500	18 Jul	1100	19 Jul	20.0	0	0	0	0
					119.0 hrs	1,414 -147* 1,267 Tabs or 10.6/hr			

* 117 tabs left in plastic reservoir tube

28 tabs left in metal reservoir tube

2 tabs found in upper pod

Table 6. Hourly water consumption activity ratings for #337, Simple during NASA/MSFC CVT/GPL III.

Observation Period (CDT)	Date 14	July 1974 15	16	17	18	19
0000-0100		0	0	0	0	0
0100-0200		0	0	0	0	0
0200-0300		0	0	0	0	0
0300-0400		0	0	0	0	0
0400-0500		0	0	0	0	0
0500-0600		0	0	0	0	0
0600-0700		0	0	0	0	0
0700-0800		0	0	0	0	0
0800-0900		0	0	3	3	
0900-1000		0	3	3	0	
1000-1100		0	3	0	3	
1100-1200		3	2	3	3	
1200-1300		3	3	3	0	
1300-1400	3	3	3	2	3	
1400-1500	3	2	3	2	0	
1500-1600	3	0	0	0	0	
1600-1700	0	3	0	0	0	
1700-1800	0	0	0	0	0	
1800-1900	0	0	0	0	0	
1900-2000	3	0	0	0	0	
2000-2100	3	0	0	0	0	
2100-2200	0	0	0	0	0	
2200-2300	0	0	0	0	0	
2300-2400	0	0	0	0	0	
No. 10-min obs. periods during which water was consumed	9	9	10	14	8	

Total of 10-min observation periods during test = 714.

A total of 50 or 7.0% of the total time spent drinking.

Table 7. Heart rate summary of the adult male pig-tailed monkey #337, Simple during NASA/MSFC CVT/GPL III. 14 July-19 July 1974.

Time	14 Jul	15 Jul	16 Jul	17 Jul	18 Jul	19 Jul	Mean Heart Rate (beats/min)	S.E.
0030		electronic drift	100	105	80	90	94	5
0130			100	100	85	100	96	4
0230			100	100	85	85	92	4
0330			105	105	85	80	94	6
0430			105	105	85	85	95	6
0530			110	105	90	85	97	10
0630			110	125	110	110	114	4
0730			125	125	110	95	114	7
0830		125	125	120	125		124	1
0930		120	125	120	130		124	2
1030		125	120	120	120		121	1
1130		120	110	120	125		119	3
1230	140	125	105	115	115		120	6
1330	125	120	110	110	120		117	3
1430	115	120	120	115	120		118	1
1530	120	125	115	120	125		121	2
1630	125	120	115	110	110		116	3
1730	110	115	120	105	105		111	3
1830	electronic drift	115	115	100	105		109	4
1930		110	110	95	110		106	4
2030		95	120	90	100		101	7
2130		95	105	90	120		102	7
2230		100	105	85	95		96	4
2330		115	115	80	90		100	9

24-hr mean ± S.E. 108 ± 2

6-hr mean ± S.E.

0000-0600	95 ± 1
0600-1200	119 ± 2
1200-1800	117 ± 1
1800-2400	102 ± 2

Table 8. Oxygen consumption (liters/hour, STPD) of monkey #337, Simple during NASA/MSFC CVT/GPL III.

Time	14 Jul 1974	15 Jul 1974	16 Jul 1974	17 Jul 1974	18 Jul 1974	19 Jul 1974	Hourly Mean	S.D.
0030	–	4.15	3.74	3.96	3.32	4.11	3.86	0.34
0130	–	4.08	3.74	3.85	4.01	4.68	4.07	0.37
0230	–	3.63	3.55	3.82	3.47	3.25	3.54	0.21
0330	–	4.04	4.89	3.63	3.59	3.44	3.72	0.24
0430	–	3.96	3.63	3.96	3.10	3.66	3.66	0.35
0530	–	3.59	3.89	3.66	3.13	3.25	3.50	0.31
0630	–	3.85	3.92	4.04	3.63	–	3.86	0.17
0730	–	4.42	4.01	4.42	4.49	–	4.34	0.22
0830	–	3.96	4.23	4.64	4.80	–	4.40	0.38
0930	–	–	4.38	5.59	5.47	–	5.15	0.67
1030	–	4.64	5.02	5.28	5.02	–	4.99	0.26
1130	–	4.23	4.49	6.08	5.59	–	5.10	0.88
1230	–	4.49	4.53	5.85	5.89	–	5.19	0.79
1330	–	4.42	4.49	5.66	5.32	–	4.97	0.61
1430	–	5.32	5.02	5.97	5.21	–	5.38	0.41
1530	–	–	5.09	5.36	4.72	–	5.06	0.32
1630	–	4.87	5.59	5.14	5.55	–	5.29	0.35
1730	–	4.87	5.44	4.38	5.44	–	5.03	0.51
1830	4.61	4.76	4.80	4.34	5.59	–	4.82	0.47
1930	4.72	4.27	4.53	3.78	5.32	–	4.52	0.57
2030	4.57	4.08	4.57	3.47	4.80	–	4.30	0.53
2130	4.76	4.08	4.23	3.74	5.02	–	4.37	0.52
2230	4.46	3.82	3.92	3.47	3.74	–	3.88	0.36
2330	4.04	4.19	4.42	3.47	3.47	–	3.92	0.43
24-Hour Mean	–	4.26	4.38	4.48	4.57	–		
S.D.	–	0.43	0.57	0.89	0.19	–		

Table 9. Carbon dioxide production (liters/hour, STPD) of monkey #337, Simple during NASA/MSFC CVT/GPL III.

Time	14 Jul 1974	15 Jul 1974	16 Jul 1974	17 Jul 1974	18 Jul 1974	19 Jul 1974	Hourly Mean	S.D.
0030	–	3.47	3.47	3.44	3.10	3.63	3.42	0.20
0130	–	3.29	3.36	3.36	3.40	3.85	3.45	0.23
0230	–	3.21	3.32	3.40	3.17	3.02	3.22	0.15
0330	–	3.25	3.51	3.21	3.25	3.13	3.27	0.14
0430	–	3.25	3.36	3.44	2.84	3.25	3.23	0.23
0530	–	3.25	3.59	3.17	2.94	2.87	3.16	0.29
0630	–	3.36	3.40	3.55	3.29	–	3.40	0.11
0730	–	3.70	3.66	3.82	3.82	–	3.75	0.08
0830	–	3.47	3.78	3.89	4.08	–	3.81	0.26
0930	–	–	3.92	4.53	4.49	–	4.31	0.34
1030	–	3.96	4.08	4.34	4.11	–	4.12	0.16
1130	–	3.36	3.78	4.83	4.61	–	4.15	0.69
1230	–	3.82	3.78	4.72	4.80	–	4.28	0.56
1330	–	3.82	3.66	4.68	4.27	–	4.11	0.46
1430	–	4.38	4.42	4.83	4.34	–	4.49	0.23
1530	–	–	4.64	4.53	4.08	–	4.42	0.30
1630	–	4.30	4.95	4.23	4.64	–	4.53	0.33
1730	–	4.11	4.80	3.63	4.46	–	4.25	0.50
1830	3.85	4.11	3.96	3.66	4.57	–	4.03	0.34
1930	3.96	3.74	3.63	3.21	4.42	–	3.79	0.44
2030	3.74	3.51	3.89	3.10	4.30	–	3.71	0.45
2130	4.01	3.70	3.36	3.36	4.38	–	3.76	0.44
2230	3.96	3.51	3.40	3.13	3.36	–	3.47	0.31
2330	3.44	3.92	3.92	3.21	3.21	–	3.54	0.36
24-Hour Mean	–	3.66	3.82	3.80	3.91	–		
S.D.	–	0.36	0.47	0.61	0.63	–		

Table 10. Respiratory quotient of monkey #337, Simple during NASA/MSFC CVT/GPL III.

Time	14 Jul 1974	15 Jul 1974	16 Jul 1974	17 Jul 1974	18 Jul 1974	19 Jul 1974	Hourly Mean	S.D.
0030	-	0.84	0.93	0.87	0.93	0.88	0.89	0.04
0130	-	0.81	0.90	0.87	0.85	0.82	0.85	0.04
0230	-	0.88	0.94	0.89	0.91	0.93	0.91	0.03
0330	-	0.80	0.90	0.88	0.91	0.91	0.88	0.05
0430	-	0.82	0.93	0.87	0.92	0.89	0.88	0.04
0530	-	0.91	0.92	0.87	0.94	0.88	0.90	0.03
0630	-	0.87	0.87	0.88	0.91	-	0.88	0.02
0730	-	0.84	0.91	0.86	0.85	-	0.87	0.03
0830	-	0.88	0.89	0.84	0.85	-	0.87	0.02
0930	-	-	0.89	0.81	0.82	-	0.84	0.04
1030	-	0.85	0.81	0.82	0.82	-	0.83	0.02
1130	-	0.79	0.84	0.79	0.82	-	0.81	0.02
1230	-	0.85	0.83	0.81	0.81	-	0.83	0.02
1330	-	0.86	0.82	0.83	0.80	-	0.83	0.03
1430	-	0.82	0.88	0.81	0.83	-	0.84	0.03
1530	-	-	0.91	0.85	0.86	-	0.87	0.03
1630	-	0.88	0.89	0.82	0.84	-	0.86	0.03
1730	-	0.84	0.88	0.83	0.82	-	0.84	0.03
1830	0.84	0.86	0.83	0.84	0.82	-	0.84	0.02
1930	0.84	0.88	0.80	0.85	0.83	-	0.84	0.03
2030	0.82	0.86	0.85	0.89	0.90	-	0.86	0.03
2130	0.84	0.91	0.79	0.90	0.87	-	0.86	0.05
2230	0.89	0.92	0.87	0.90	0.90	-	0.90	0.02
2330	0.85	0.94	0.89	0.93	0.93	-	0.91	0.04
24-Hour Mean	-	0.86	0.87	0.85	0.86	-		
S.D.	-	0.04	0.04	0.04	0.05	-		

Table 11. Consecutive 12-hour means of oxygen consumption, carbon dioxide production, and respiratory quotient for monkey #337, Simple during NASA/MSFC CVT/GPL III.

12-Hour Period	$\dot{V}_{O_2}$ liters/hr (STPD)	$\dot{V}_{CO_2}$ liters/hr (STPD)	R.Q.
1800 14 Jul 74 – 0600 15 Jul 74	4.22	3.56	0.85
0600 15 Jul 74 – 1800 15 Jul 74	4.51	3.83	0.85
1800 15 Jul 74 – 0600 16 Jul 74	3.97	3.59	0.91
0600 16 Jul 74 – 1800 16 Jul 74	4.68	4.07	0.87
1800 16 Jul 74 – 0600 17 Jul 74	4.11	3.52	0.86
0600 17 Jul 74 – 1800 17 Jul 74	5.20	4.30	0.83
1800 17 Jul 74 – 0600 18 Jul 74	3.57	3.20	0.90
0600 18 Jul 74 – 1800 18 Jul 74	5.09	4.25	0.84
1800 18 Jul 74 – 0600 19 Jul 74	4.19	3.67	0.88

Table 12. Sum of partial pressures measured by NASA mass spectrometer[1] compared with total barometric pressure measured by an electronic barometer.

Date	Time	Gas Sample	P_{CO_2} (torr)	P_{O_2} (torr)	P_{N_2} (torr)	P_{H_2O} (torr)	P_{total} (torr)	P_B (torr)	Diff.[2] (torr)	% Diff.[3]
14 Jul 74	1600	Cabin	0	155.7	580.8	6.7	743.2	746.4	3.2	0.4
		Pod	6.6	147.7	578.7	12.4	745.4	746.4	1.0	0.1
15 Jul 74	0910	Cabin	0	154.4	577.7	9.6	741.7	746.1	4.4	0.6
		Pod	5.9	147.3	575.2	16.0	744.4	746.1	1.7	0.2
15 Jul 74	1446	Cabin	0	154.3	576.9	7.6	738.8	743.6	4.8	0.7
		Pod	6.0	146.9	572.3	18.0	743.2	743.6	0.4	0.1
16 Jul 74	0900	Cabin	0	154.9	579.4	9.1	743.4	746.1	2.7	0.4
		Pod	6.1	146.7	572.8	16.6	742.2	746.1	3.9	0.5
16 Jul 74	1445	Cabin	0	154.8	578.5	9.1	742.4	745.2	2.8	0.4
		Pod	8.0	146.0	576.0	18.1	748.1	745.2	-2.9	-0.4
17 Jul 74	0834	Cabin	0	155.7	581.8	9.0	746.5	749.6	3.1	0.4
		Pod	6.5	147.9	578.7	18.1	751.2	749.6	-1.6	-0.2
17 Jul 74	1502	Cabin	0	155.1	580.5	8.6	744.2	748.3	4.1	0.6
		Pod	9.4	144.2	571.8	20.2	745.6	748.3	2.7	0.4
18 Jul 74	0841	Cabin	0	156.8	585.9	7.8	750.5	752.0	1.5	0.2
		Pod	9.6	146.4	583.8	16.1	755.9	752.0	-3.9	-0.5
18 Jul 74	1445	Cabin	0	155.7	581.5	9.5	746.7	750.3	3.6	0.5
		Pod	6.7	147.4	577.1	18.0	749.2	750.3	1.1	0.2
19 Jul 74	0811	Cabin	0	156.4	583.6	8.0	748.0	751.1	3.1	0.4
		Pod	6.0	148.4	579.9	16.3	750.6	751.1	0.5	0.1
									Mean	0.2%

[1] Based on direct readings of voltage outputs on a digital voltmeter following adjustment of MS inlet pressure to nominal value.

[2] Diff. = $P_B - P_{total}$.

[3] % Diff. = $100(P_B - P_{total})/P_B$.

Table 13. Stability of NASA mass spectrometer as indicated by gas partial pressure measurements of calibration gas mixtures.

Date	Time	Cylinder #1 P_{CO_2} (torr)	Cylinder #1 P_{O_2} (torr)	Cylinder #1 P_{N_2} (torr)	Cylinder #2 P_{CO_2} (torr)	Cylinder #2 P_{O_2} (torr)	Cylinder #2 P_{N_2} (torr)	Cylinder #3 P_{CO_2} (torr)	Cylinder #3 P_{O_2} (torr)	Cylinder #3 P_{N_2} (torr)
14 Jul 74	1600	7.3	151.5	587.6	10.3	147.8	588.3	14.6	142.7	589.1
15 Jul 74	0910	7.7	151.5	586.9	10.4	145.6	590.1	14.6	142.7	588.8
15 Jul 74	1446	7.5	151.0	585.1	10.5	147.3	585.8	14.6	145.7	583.3
16 Jul 74	0900	7.7	152.7	585.7	10.6	147.0	594.8	14.6	143.2	588.3
16 Jul 74	1445	7.7	151.3	586.2	10.6	145.4	589.2	14.6	144.2	586.4
17 Jul 74	0834	7.7	152.2	589.7	10.6	146.3	592.7	14.7	143.4	591.5
17 Jul 74	1502	7.7	151.9	588.7	10.6	146.0	591.7	14.7	143.1	590.5
18 Jul 74	0841	7.5	152.6	591.9	10.7	146.7	595.3	14.7	143.8	593.5
19 Jul 74	0811	7.7	152.5	590.9	10.7	146.6	593.8	14.7	145.4	591.0
Mean		7.6	151.9	588.1	10.6	146.5	591.3	14.6	143.8	589.2
S.D.		0.1	0.6	2.4	0.1	0.8	3.2	0.1	1.1	3.0
C.V. (%)		1.9	0.4	0.4	1.3	0.5	0.5	0.4	0.8	0.5
n		9	9	9	9	9	9	9	9	9

Based on strip chart readings following adjustment of MS inlet pressure to nominal value.

P_{N_2} obtained by difference; i.e., $P_B - P_{O_2} - P_{CO_2}$.

Table 14. Effect of 51 minutes of 20 torr LBNP on heart rate when applied to monkey #337, Simple in the upright position during NASA/MSFC CVT/GPL III.

Date	Day	Heart Rate (beats/min)*			
		Control	LBNP	Recovery	LBNP - Control
July 14	1	130	145	120	+ 15
15	2	120	135	110	+ 15
16	3	115	125	110	+ 10
17	4	115	130	110	+ 15
18	5	105	125	110	+ 20
Mean		117	132	112	+ 15

* All data shown were obtained during last 5 minutes of the control, LBNP and recovery periods, each of 15 minutes duration.

APPENDIX A

Acronym List

ARC	Ames Research Center
BCR	Bioclean Room at MSFC
CDT	Central Daylight Time
CVT	Concept Verification Test
ECG	Electrocardiogram
EPL	Environmental Physiology Laboratory
GPL	General Purpose Laboratory
JSC	Johnson Space Center
LBNP	Lower-body negative pressure
MS	Mass spectrometer
MSFC	Marshall Space Flight Center
PDT	Pacific Daylight Time

APPENDIX B

Procedures for Payload Specialist during nutrient intake assessment, respiratory gas exchange calibration, and LBNP test periods of monkey pod during NASA/MSFC CVT/GPL III.

Food and water should be checked prior to the initiation of the following procedures in the morning and lastly in the afternoon.

Water is limited to 1,000 ml per day. Water consumption or the amount of water left in the graduate cylinder should be noted both in a.m. and p.m. Water is added only at the a.m. observation, bringing it up to a 1,000 ml level.

Food tablets are added at the a.m. and p.m. checkpoints and additional tablets may be added at other times of the day. The time of the offering and the number of food tablets added to the feeder should be properly noted in the log book.

Note: For a.m. delete the LBNP test procedures (1-3) (23-28) (35-41).
For p.m. carry out all procedures in numerical order.

(1) Set Brush recorder chart speed at 0.20 mm/sec.

(2) Observe heart rate record and Bio-tach beat indicator lamp on Brush recorder to determine if ECG input is triggering counter. If lamp is not flashing in regular rhythm and subject is quiet turn THRESHOLD to limit in counterclockwise direction and then gradually in clockwise direction until light flashes steadily.

(3) Record heart rate of subject for 15 min control period. Make notes on chart of subject behavior which may influence heart rate (e.g. drinking, eating, sleeping, struggling). Begin 45 min LBNP sequence.

4. Pre-set calibration gas flows by adjusting Control Valves on all cylinders to insure out-board leak in calibration gas line (float on Cal. Gas Flow Indicator on outside console should be approx. 3/4 of way up in the column).

5. Leave "zero" cylinder flow ON, and shut off Main Valves on remaining cylinders to conserve calibration gases.

6. Obtain "UCB Monkey-Pod Instrumentation Console Data" sheet and record data indicated below.

7. Place MS Outputs/DVM Switch (A) to Voltage position and record MS inlet pressure transducer voltage on DVM (B).

8. Adjust Sample Outlet Valve (C), as needed, to set voltage at 3.500 $\pm$ 0.010 volts.

9. Place MS Outputs/DVM Switch to Current position and record MS ion pump current (measured as a negative voltage) on DVM.

   The nominal reading is between -100 and -10 millivolts.

10. Place MS Outputs/DVM Switch to the CO_2, O_2, N_2, and H_2O positions and record MS signal outputs on DVM for P_{CO_2}, P_{O_2}, P_{N_2}, and P_{H_2O} respective for POD air.

    During normal running mode, the MS sampling system will be set with the Sample Valve (D) in the Pod position, and the Calibration Valve (E) in the Cabin Air position.

11. Turn Sample Valve from Pod position to Calibration position.

    MS should now be sampling cabin air.

12. Allow approximately 5 minutes before reading the MS signal outputs for cabin air indicated below in Step 18.

13. Record upper pod mass flow rate on panel meter of Flowmeter (F).

14. Adjust flow, as needed, with upper pod Air Flow Control (G) to 8,000 ± 200 cc/minute.

15. Record temperatures on digital display of Thermometer (H) for upper pod, flowmeter, and lower pod with Select Probe Switch (I) on the probe A, probe B, and probe C positions respectively.

16. After recording temperatures, return Select Probe Switch to Probe B position.

17. Place MS Outputs/DVM Switch to Voltage position and adjust Sample Outlet Valve, as needed, to set voltage at 3.500 ± 0.010 volts.

18. Place MS Outputs/DVM Switch to the CO_2, O_2, N_2, and H_2O positions and record MS signal outputs on DVM for P_{CO_2}, P_{O_2}, P_{N_2}, and P_{H_2O} respectively for CABIN air.

19. Complete data sheet by obtaining barometric pressure from elsewhere (an on-line P_B sensor not yet installed in console).

20. Turn Calibration Valve from Cabin Air position to Cylinder position.

    MS should now be sampling from the "zero" calibration gas cylinder.

21. Place MS Outputs/DVM Switch to Voltage position and adjust Sample Outlet Valve, as needed, to set voltage at 3.500 ± 0.010 volts.

(22) At end of 15 min of heart rate recording, shut off LOWER POD VENT. FAN.

(23) Place stopper in LOWER POD AIR INLET PORT.

(24) Turn LOWER POD EXHAUST VALVE to LBNP.

(25) Turn on LBNP POWER.

(26) Gradually increase voltage on LBNP CONTROL over 15 sec period to give UPPER/LOWER POD DIFF. PRESSURE of 10 inches of water. Adjust the voltage as needed to maintain this pressure for 15 min.

(27) During LBNP repeat procedures described in (2) and (3).

28. Allow approximately 5 min for stabilization of the readings and adjust base lines, as needed, for the P_{CO_2}, P_{O_2}, P_{N_2}, and P_{H_2O} channels on the recorder with the "zero" calibration gas.

    P_{CO_2} channel base line set at 5 divisions (0.8 mm/division from left or right of chart depending on polarity of recorder.

    P_{O_2} channel base line set at 5 divisions from right or left of chart depending on polarity of recorder.

    P_{N_2} channel base line set at mid-scale of chart.

    P_{H_2O} channel base line set at 5 divisions from left or right of chart depending on polarity of recorder.

29. Run calibration curves for P_{CO_2} and P_{O_2} on recorder by connecting calibration gas line, in turn, to cylinders 1, 2, and 3.

    Since the gas flows were pre-set earlier by means of the Control Valves, cracking the Main Valves on the cylinders should provide the correct flow of calibration gases to the MS.

    Allow approximately 5 min for each cylinder.

30. Re-connect the calibration gas line to the "zero" cylinder, and shut off Main Valves on remaining cylinders.

31. Return to monkey pod instrumentation console and turn Calibration Valve from Cylinder position to Cabin Air position.

32. Turn Sample Valve from Calibration position to Pod position.

33. Adjust Sample Outlet Valve, as needed, to set MS inlet pressure transducer voltage at 3.500 ± 0.010 volts.

34. Shut off Main Valve on "zero" calibration gas cylinder.

(35) At end of LBNP decrease voltage with LBNP CONTROL knob to zero over 15 sec period.

(36) Turn off LBNP POWER.

(37) Turn LOWER POD EXHAUST VALVE to VENT.

(38) Remove stopper from LOWER POD AIR INLET PORT.

(39) Turn on LOWER POD VENT. FAN.

(40) At end of LBNP period repeat procedures described in (2) and (3) during 15 min recovery period.

(41) At end of recovery period set Brush recorder chart speed at 0.05 mm/sec.

APPENDIX C

LBNP calibration procedures for monkey pod during NASA/MSFC CVT/GPL III

Note: The calibration of the pressure transducer and gauge should be done just before the monkey pod is connected to and just after it is disconnected from the console inside the Spacelab. The calibration of the Biotachometer is to be done at least daily in the A.M. It is assumed that these calibrations will be conducted by UCB-EPL personnel.

A. CALIBRATION OF PRESSURE TRANSDUCER AND GAUGE

Transducer and gauge are located in uppermost section of console inside Spacelab. Transducer pre-amplifier located on Brush recorder outside Spacelab.

1. On inside console turn PRESSURE INPUT VALVE to CAL.
2. On outside console transducer pre-amplifier set SENSITIVITY to OFF and adjust pen POSITION to convenient base line (one large division to left of right margin of paper).
3. Increase SENSITIVITY in steps and move pen back to base line with BALANCE CONTROL. Set SENSITIVITY to 10/DIV.
4. On inside console, attach manometer system to PRESSURE CAL. PORT by removing cap and attaching Swagelok fitting with 2 wrenches.
5. Close leak on rubber pressure bulb and apply 20 in. water pressure.
6. On outside console, set pen at eight large divisions to left of base line by adjusting GAIN control.
7. Reduce pressure to 10 in. water momentarily and then drop to 0 in. water by opening leak valve on bulb.
8. If base line unchanged, proceed to next step; if changed, set pen POSITION to base line and repeat steps 5 - 7.

9. Write pressure values of 20, 10 and 0 in. water on strip chart on appropriate line.

10. Remove manometer system from PRESSURE CAL. PORT and turn PRESSURE INPUT VALVE to POD.

B. CALIBRATION OF BIOTACHOMETER

The Bio-tach pre-amplifier is located on Brush recorder outside the Spacelab.

1. Turn SENSITIVITY to OFF and RESPONSE to BEAT.
2. Set pen position on right edge of chart with ZERO control.
3. Turn SENSITIVITY to CAL. and set pen position on left edge of chart with 50 DIV. control.
4. Turn SENSITIVITY to 5 BEATS/MIN/DIV. and RESPONSE to AVE.
5. If THRESHOLD light is not flashing in regular rhythm and it is expected that the subject's heart beat should be steady, then turn THRESHOLD to limit in counterclockwise direction and then gradually in clockwise direction until light flashes in regular rhythm.
6. The ECG can be obtained at any time desired by turning the SENSITIVITY to ECG.